IS PARABOLIC TROUGH SOLAR POWER PLANT TECHNOLOGY READY FOR ITS NEXT GROWTH SURGE?

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WREC
Denver, Colorado
31 August 2004

YES

but why?

Excellent operating experience
Technology advances
Stronger supplier base
Large plants in development
Opportunities for significant new deployments

Parabolic Trough Collector

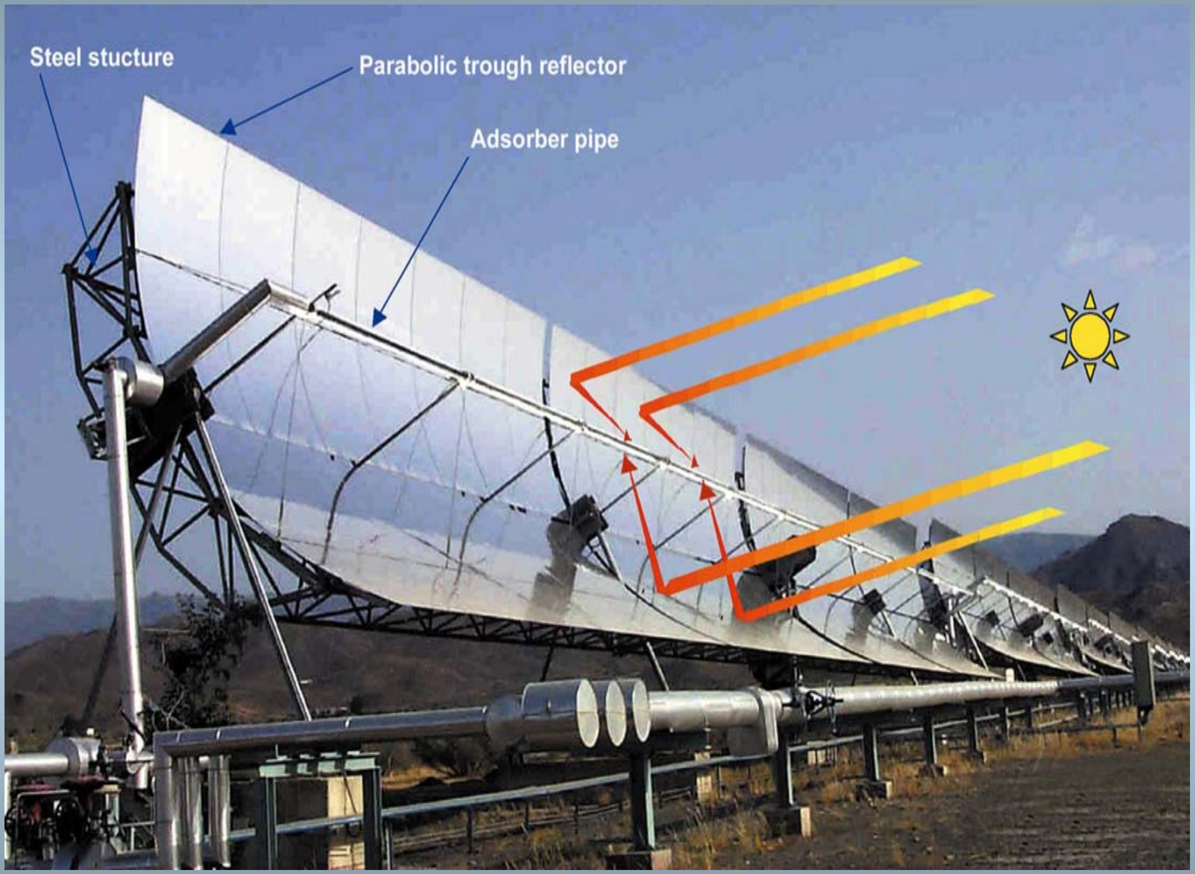


Illustration courtesy of Solar Millennium

- *Typically tracks sun E-W on N-S axis*
- *High temperature oil flows through receiver*
- *Receiver highly efficient due to vacuum annulus and selective surface*
- *Major cost elements: structure, receivers, reflectors*
- *Mirror washing proven to be very effective*

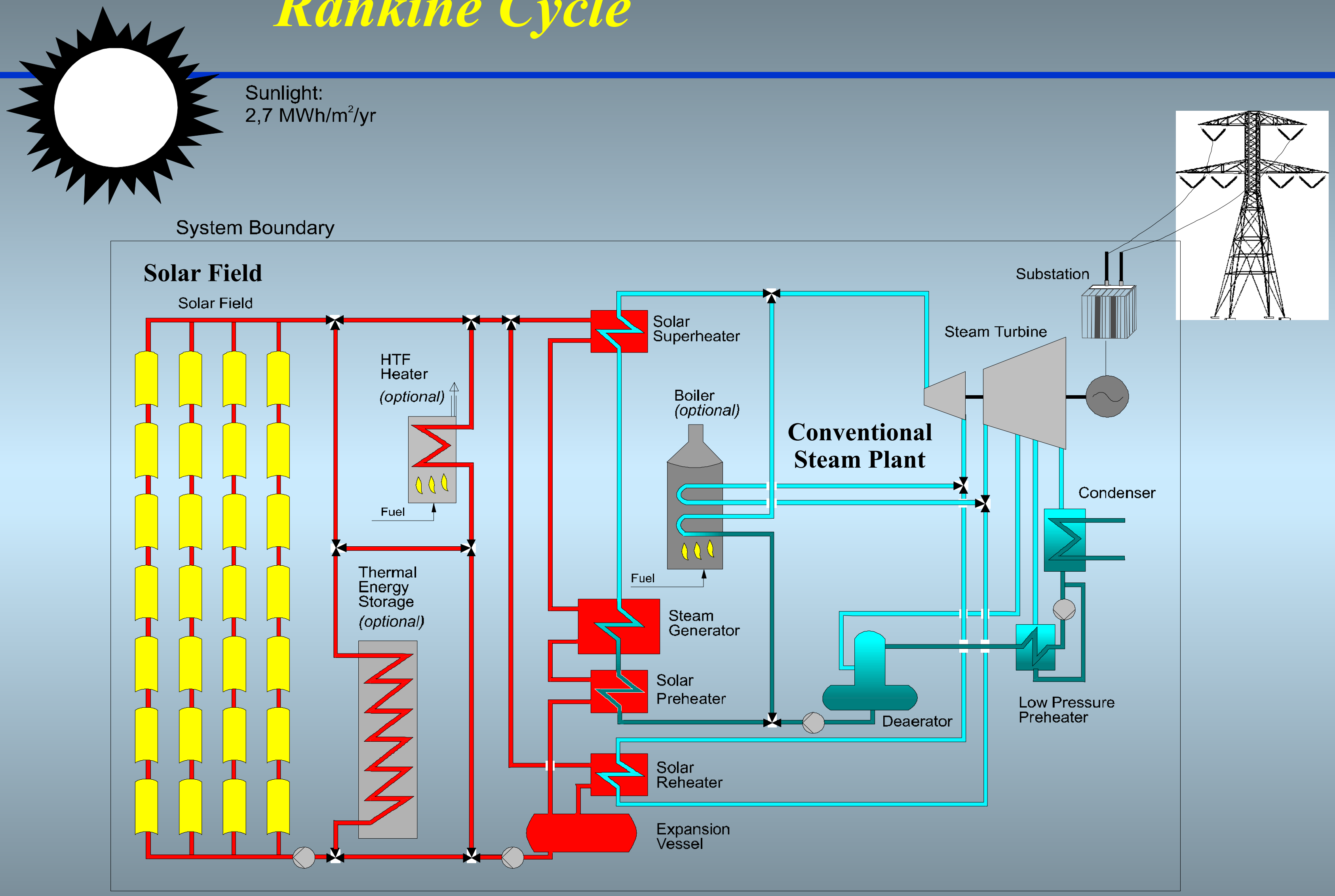
Key Technical Characteristics

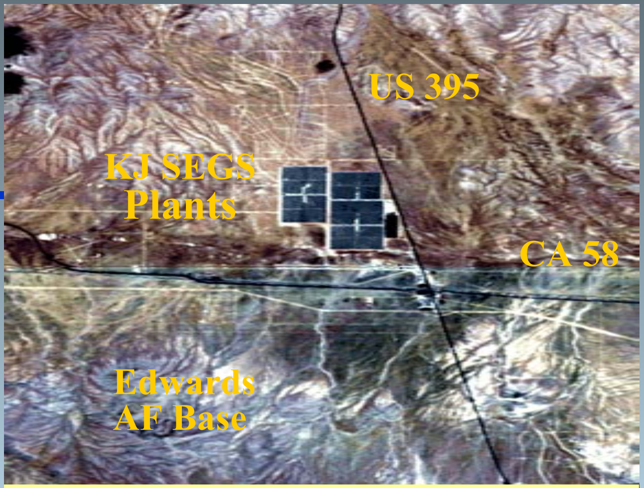
- Parabolic trough collectors concentrate direct beam radiation onto receiver, heating circulating high temperature fluid at 400C
- Via shell-and-tube heat exchangers, solar field heat used to generate high temperature, high pressure steam
- Larger power systems can be either steam Rankine cycles or combined cycles, from 30MWe to over 300 MWe
- Systems can use fossil fuel or thermal storage to raise capacity factor or shift time of electrical production

Key Technical Characteristics (continued)

- Dispatchability achieved with thermal storage or hybrid operation (with fossil) => approaches firm power
- Proven long-term operation in California
- Technology development path to competitive electricity cost levels identified
- Ready for rapid manufacturing scale-up to GW level deployment

Solar Electric Generating System
Rankine Cycle



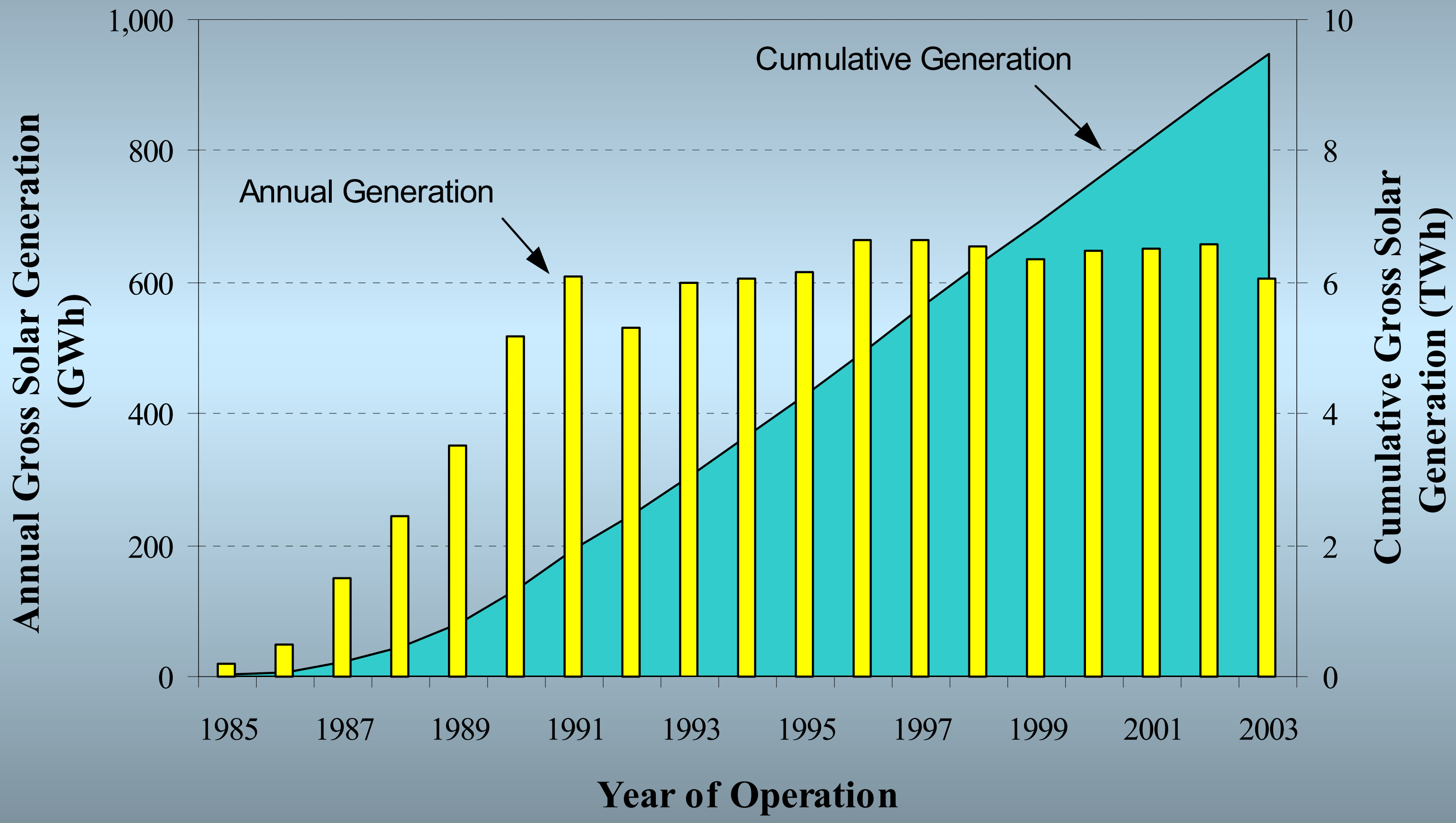


- 354 MWe installed
- 7000 GWH operations
- 110% peak availability
- $1.25 Billion invested
- Matured O&M procedures
- Technical advances lowered costs

Kramer Junction, Calif.
Five 30-MWe Trough Plants

<u>Kramer Junction Operational Experience</u>

Electrical Output



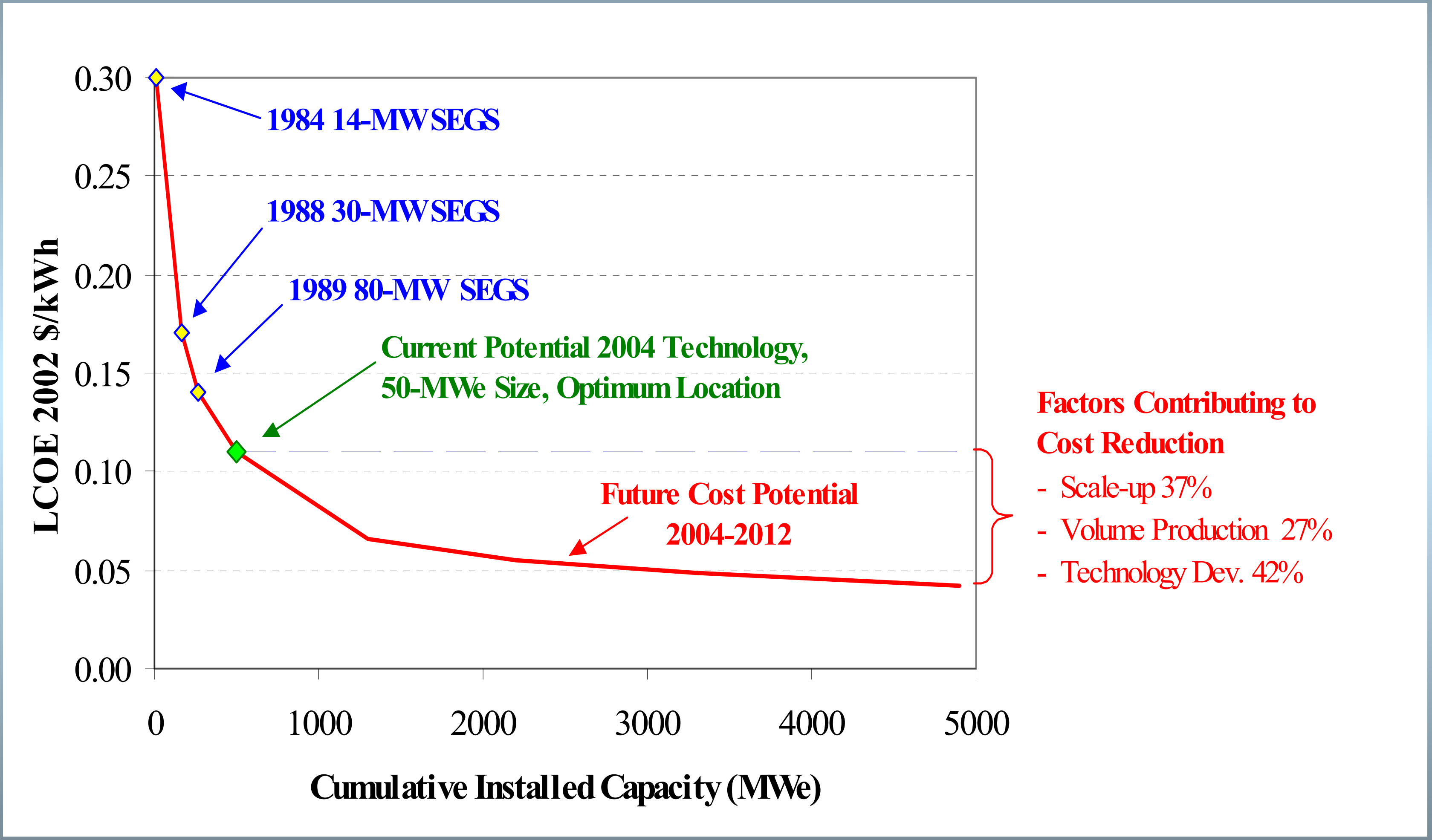
Cost Reduction Opportunities

Parabolic Trough Technology

- **Plant Size**
- Concentrator Design
- **Advanced Receiver Technology**
- **Thermal Energy Storage**
- O&M
- Design Optimization/Standardization
- Power Park
- Competition
- **Financial**

Trough Development Scenario

Breakdown of Cost Reduction (Sargent & Lundy)



Current State-of-the-Art

50 MWe Trough Plant

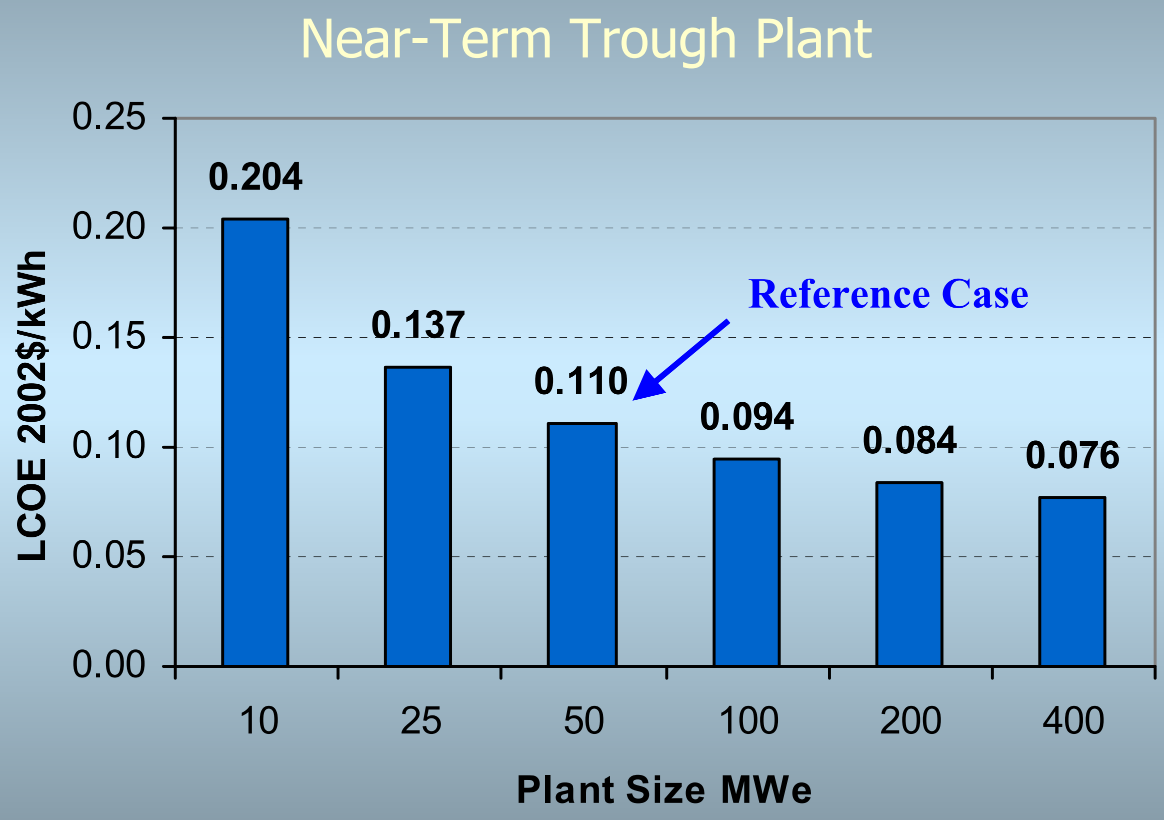
- **Current State-of-the-Art (Plant built today)**
  - 50 MWe (~100 bar, 700F, 37.5% gross)
  - LS-2 Collectors (391 C)
  - Receiver – Solel UVAC
  - Solar only or hybrid
  - Solar multiple 1.5
  - No thermal storage
  - DNI 8.0 kWh/m^2-day

Site: Kramer Junction	Solar Only	Hybrid (25%)
Plant size, net electric [MWe]	50	50
Collector Aperture Area [km^2]	0.312	0.312
Thermal Storage [hours]	0	0
Solar-to-electric Efficiency. [%]	13.9%	14.1%
Plant Capacity Factor [%]	29.2%	39.6%
Capital Cost [$/kWe]	2745	2939
O&M Cost [$/kWh]	0.024	0.018
Fuel Cost [$/kWh]	0.000	0.010
Levelized Cost of Energy [2002$/kWh]	0.110	0.096

Current Cost
11¢/kWh

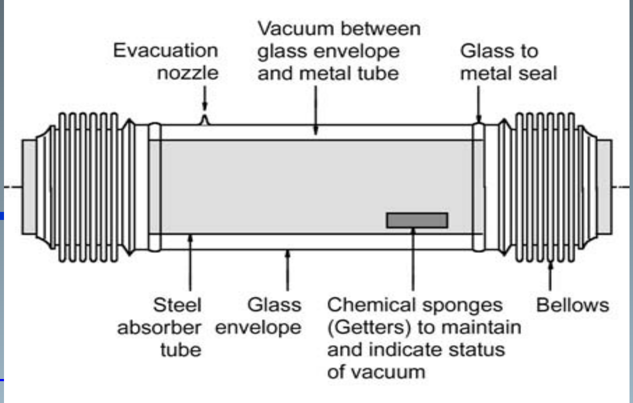
Plant Size

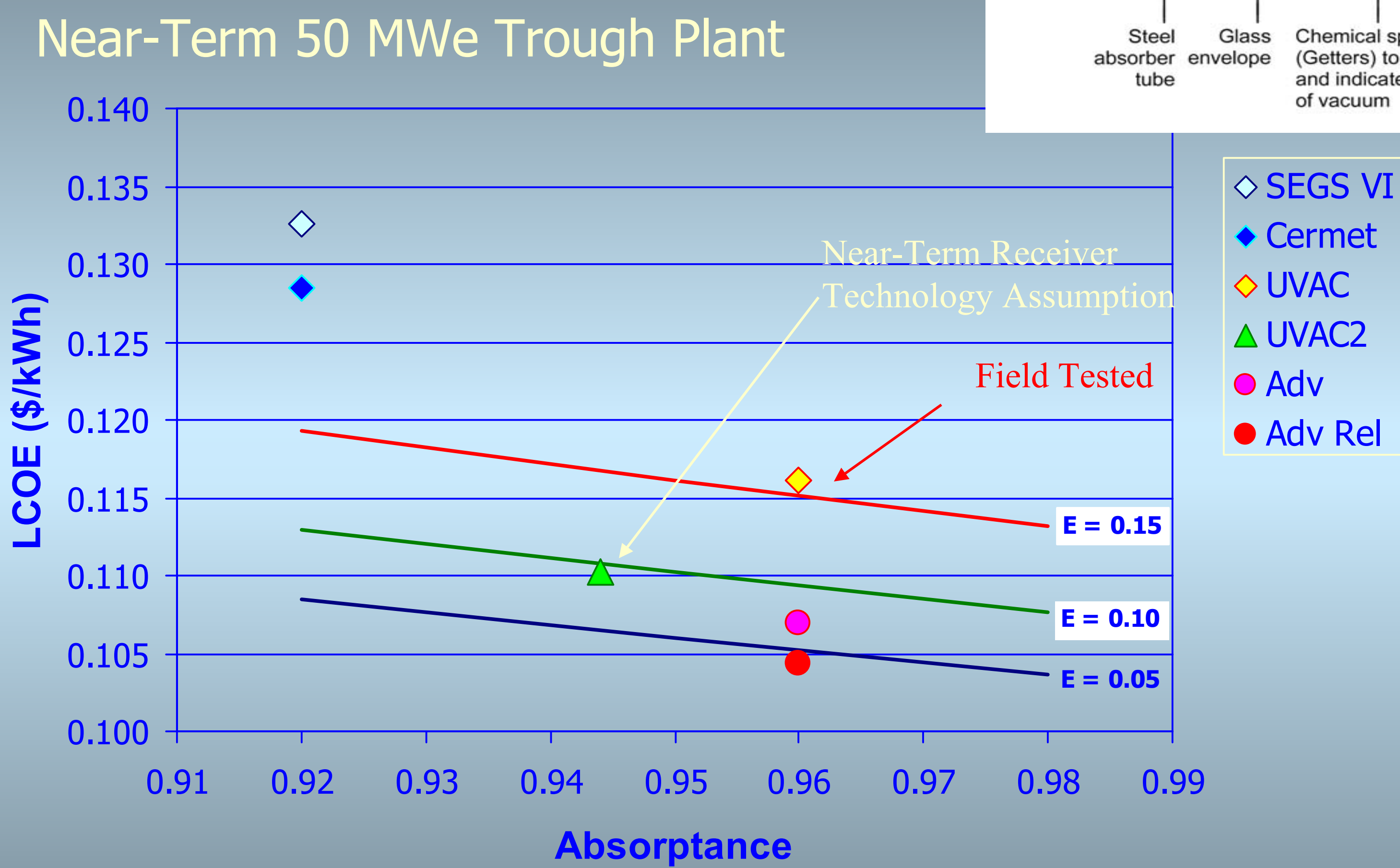
Impact on Cost of Energy



Trough Receiver Technology

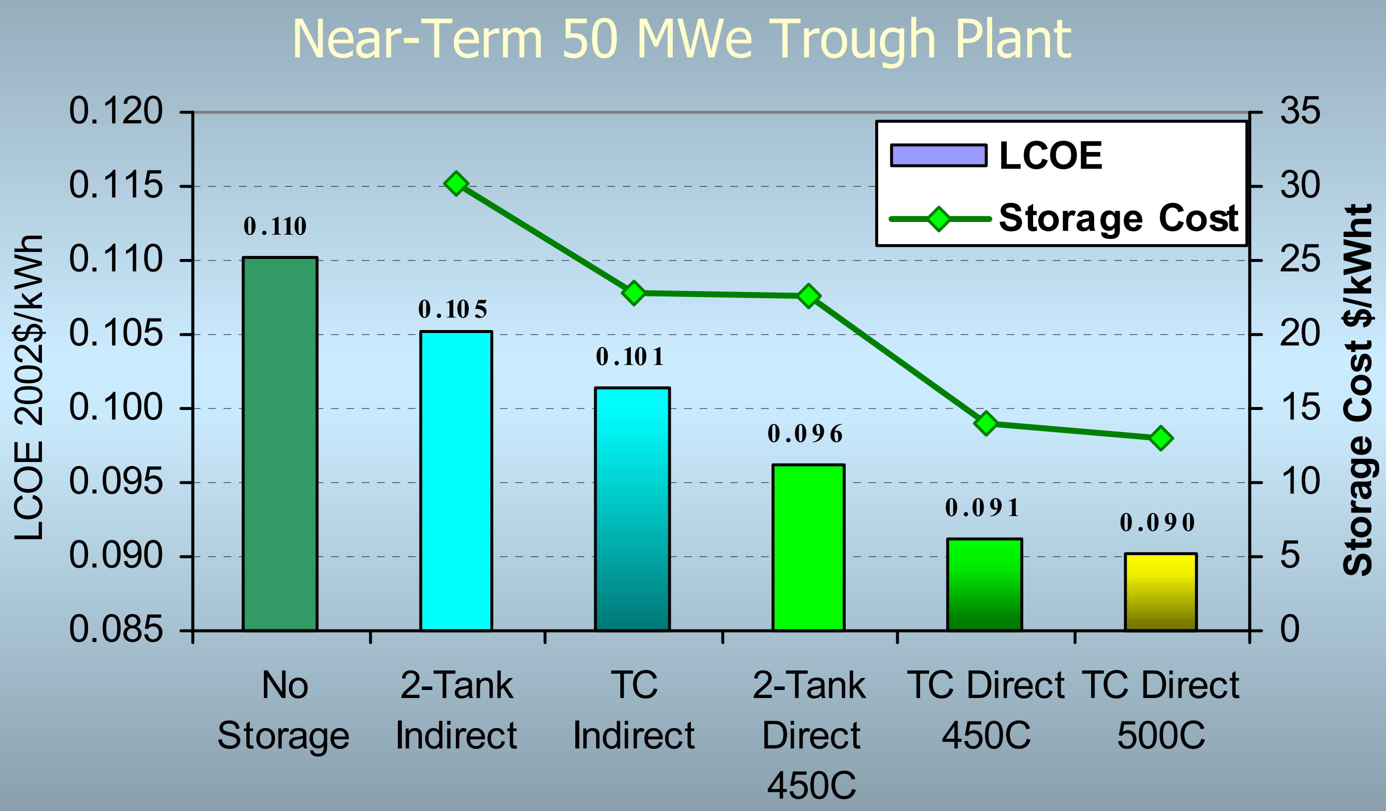
Impact on the Cost of Energy





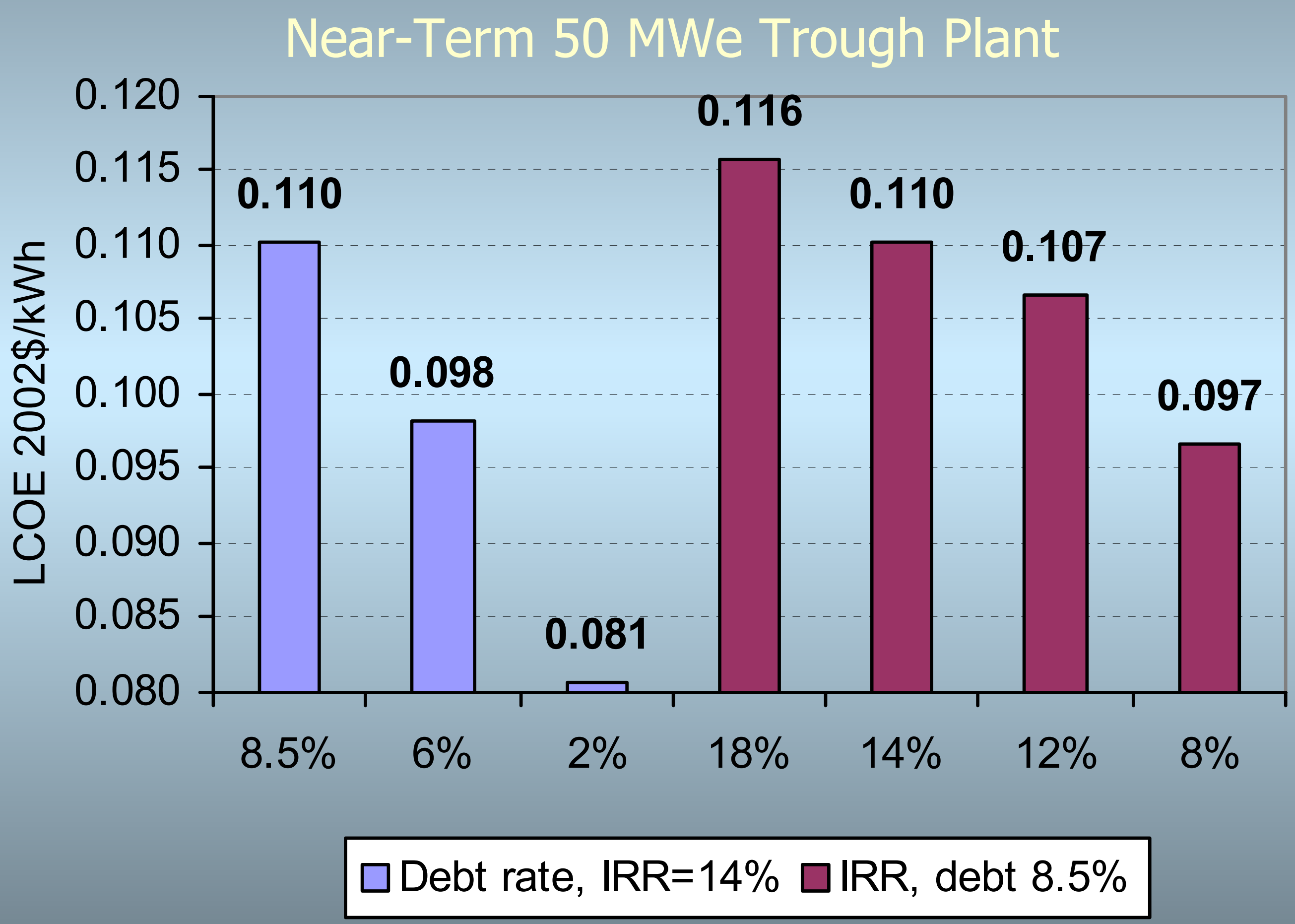
Thermal Storage Technology

Impact on Cost of Energy



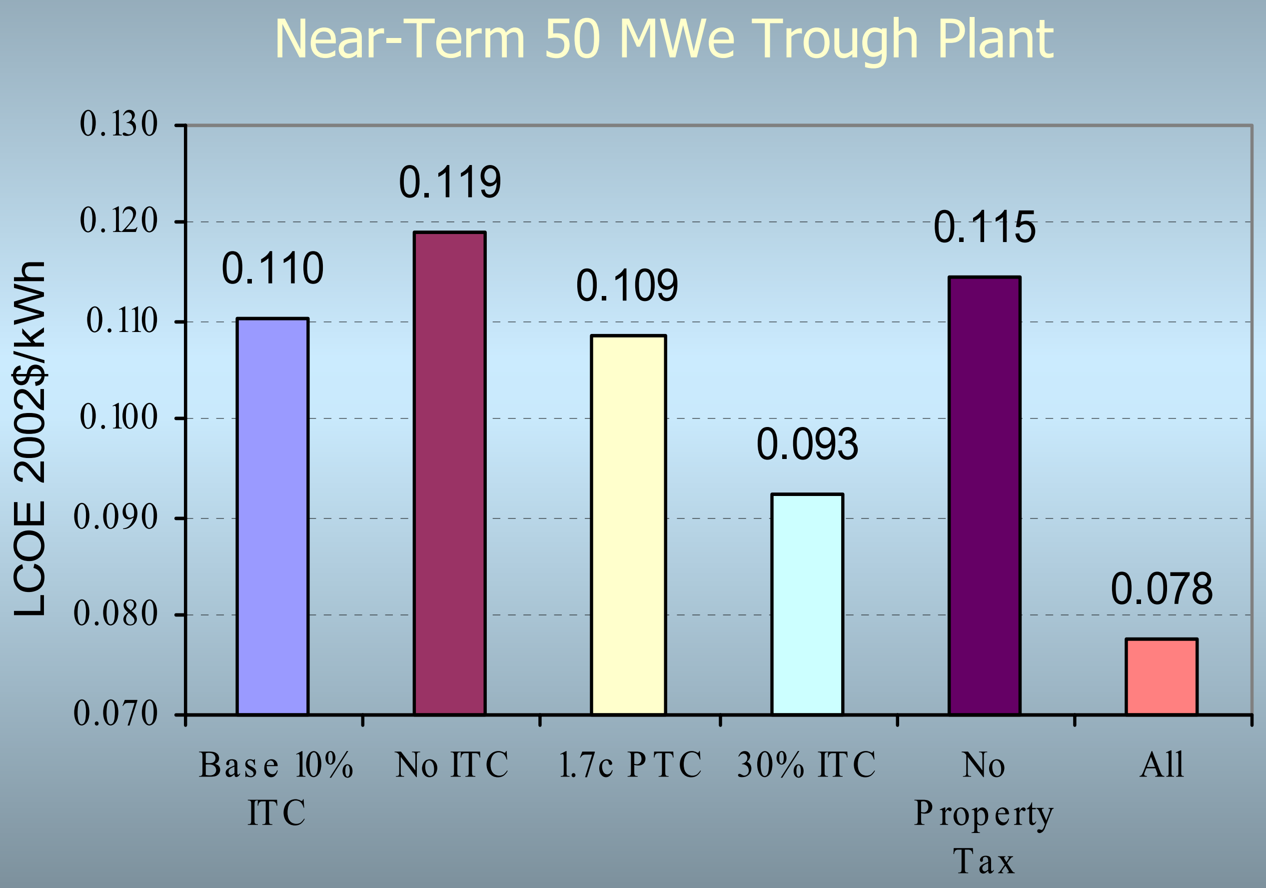
Cost of Capital

Impact on Cost of Energy



Tax Incentives

Impact on Cost of Energy



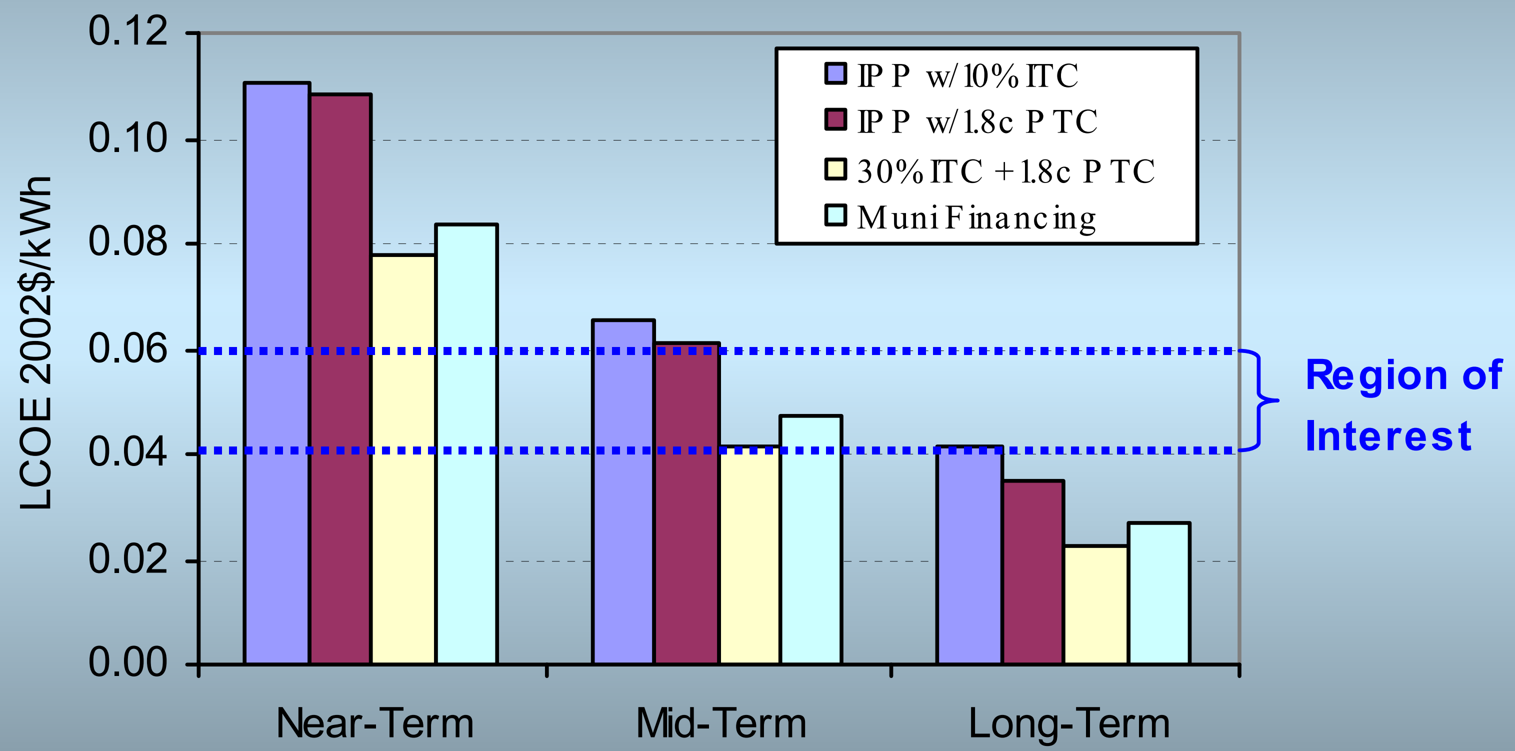
Future Development Scenario

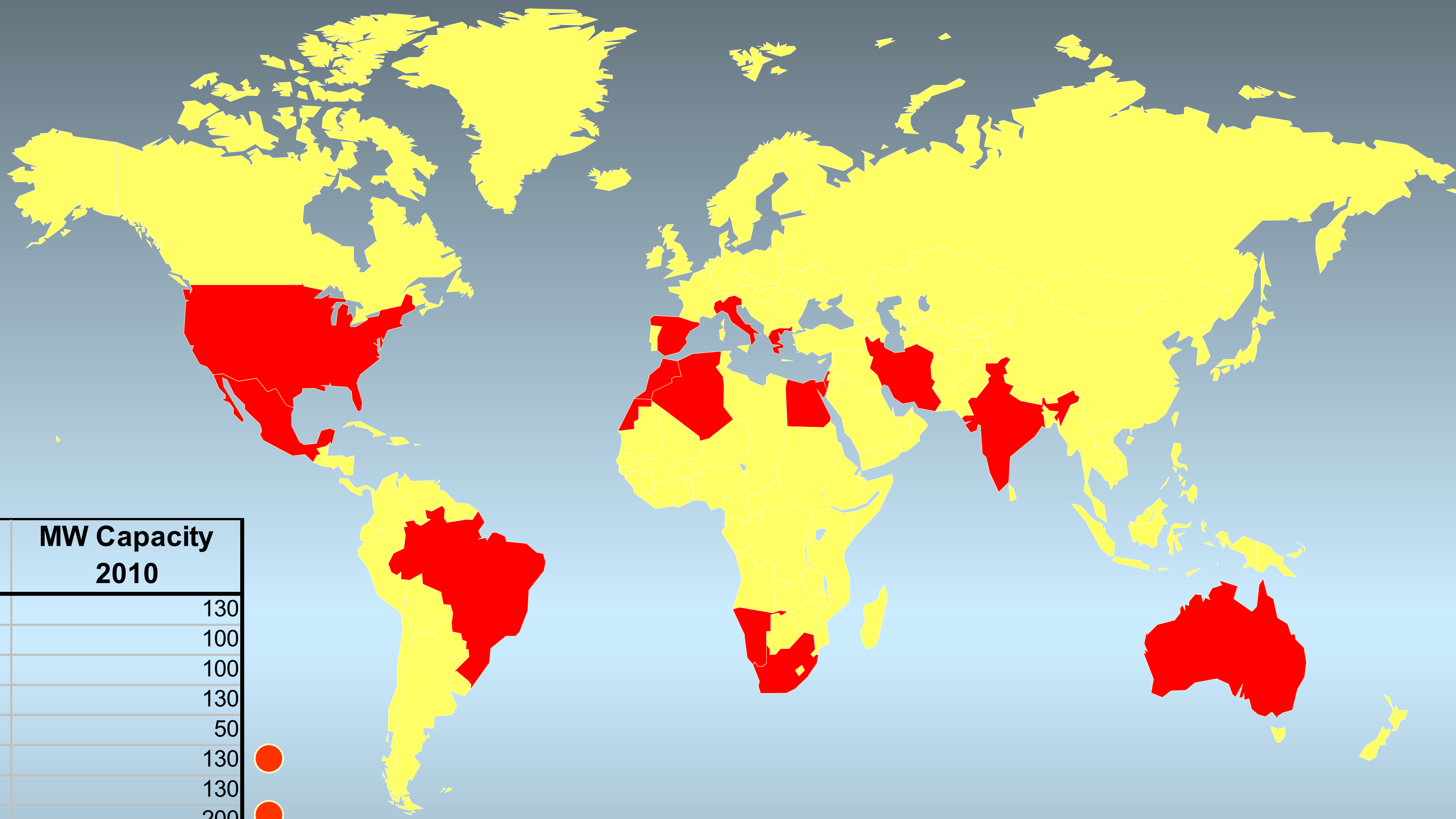
Parabolic Trough Technology

	SEGS VI 1989	Near-Term	Mid-Term	Long-Term
Plant Size: MWe Solar Multiple	30 1.2	50 1.5	100 2.5	400 2.5
Collector Receiver	LS-2 Luz	LS-2 UVAC2	LS-3+ Adv	Adv Adv
HTF	VP-1 390 C	VP-1 390 C	Salt 450 C	Salt 500 C
TES	NA	NA	12 hrs TC Dir	12 hrs TC Dir
Capacity Factor	22%	30%	56%	56%
Solar to Electric η	10.6%	13.4%	16.2%	17.2%
Cost Reduction			5%	20%
Capital Cost $/kWe	2954	2865	3416	2225
O&M Cost $/kWh	0.0462	0.0233	0.0103	0.0057

Trough Power Plant Scenarios

with Different Financing Assumptions





Country	MW Capacity 2010
Algeria	130
Australia	100
Brazil	100
Egypt	130
Greece	50
India	130
Iran	130
Israel	200
Italy	100
Jordan	130
Mexico	300
Morocco	150
Namibia	100
South Africa	100
Spain	200
United States	200
TOTAL	**2250**

CSP Market Areas and Lead Near-Term Opportunities

Market Pull Required for Success

- Market aggregation
- Incentives
- Favorable financing
- Policy changes
- Electricity production must be high to seriously impact reduction of green house gases
- Ultimate price goals tied to GW-scale deployment in 10-100 GW range

Summary

- Huge domestic resource potential
- Trough technology has significant opportunities for cost reduction
- Trough technology could directly compete with fossil power technologies in the long-term
- Market or financial incentives needed for early plants